AD-A145 213 DEVELOPMENT OF A PRODUCTION ORDER RELEASE METHODOLOGY 1/1
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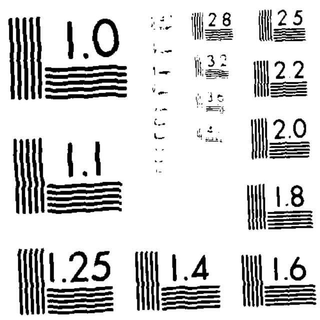


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## REPORT DOCUMENTATION PAGE

(14)

| | |
|---|---|
| 1a REPORT SECURITY CLASSIFICATION UNCLASSIFIED | 1b RESTRICTIVE MARKINGS |
| 2a SECURITY CLASSIFICATION AUTHORITY | 3 DISTRIBUTION/AVAILABILITY OF REPORT Approved for public release; distribution unlimited. |
| 2b DECLASSIFICATION/DOWNGRADING SCHEDULE | |
| 4 PERFORMING ORGANIZATION REPORT NUMBER(S) | 5 MONITORING ORGANIZATION REPORT NUMBER(S) AFOSR-TR- 0726 |
| 6a NAME OF PERFORMING ORGANIZATION Pennsylvania State University; 6b OFFICE SYMBOL (If applicable) | 7a. NAME OF MONITORING ORGANIZATION Air Force Office of Scientific Research |
| 6c ADDRESS (City, State, and ZIP Code) Dept of Industrial & Management Systems Engineering, 207 Hammond Bldg, University Park PA 16802 | 7b. ADDRESS (City, State, and ZIP Code) Directorate of Mathematical & Information Sciences, AFOSR, Bolling AFB DC 20332 |
| 8a NAME OF FUNDING/SPONSORING ORGANIZATION AFOSR; 8b OFFICE SYMBOL (If applicable) NM | 9 PROCUREMENT INSTRUMENT IDENTIFICATION NUMBER AFOSR-83-0333 |
| 8c. ADDRESS (City, State, and ZIP Code) Bolling AFB DC 20332 | 10 SOURCE OF FUNDING NUMBERS: PROGRAM ELEMENT NO. 61102F; PROJECT NO 2304; TASK NO. D9; WORK UNIT ACCESSION NO |

11. TITLE (Include Security Classification)
DEVELOPMENT OF A PRODUCTION ORDER RELEASE METHODOLOGY

12. PERSONAL AUTHOR(S)
D.J. Medeiros

| 13a TYPE OF REPORT | 13b. TIME COVERED | 14 DATE OF REPORT (Year, Month, Day) | 15 PAGE COUNT |
|---|---|---|---|
| Final | FROM 1/9/83 TO 31/5/84 | JUL 84 | 31 |

16. SUPPLEMENTARY NOTATION

| 17. COSATI CODES | | | 18. SUBJECT TERMS (Continue on reverse if necessary and identify by block number) |
|---|---|---|---|
| FIELD | GROUP | SUB-GROUP | |
| | | | |
| | | | |

19. ABSTRACT (Continue on reverse if necessary and identify by block number)

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| | |
|---|---|
| 20. DISTRIBUTION/AVAILABILITY OF ABSTRACT ☒ UNCLASSIFIED/UNLIMITED ☐ SAME AS RPT. ☐ DTIC USERS | 21. ABSTRACT SECURITY CLASSIFICATION UNCLASSIFIED |
| 22a NAME OF RESPONSIBLE INDIVIDUAL Dr. Robert N. Buchal | 22b TELEPHONE (Include Area Code) (202) 767- 4939; 22c. OFFICE SYMBOL NM |

DD FORM 1473, 84 MAR — 83 APR edition may be used until exhausted. All other editions are obsolete.

SECURITY CLASSIFICATION OF THIS PAGE
UNCLASSIFIED

84 08 30 047

AFOSR-TR

FINAL REPORT

DEVELOPMENT OF A PRODUCTION ORDER
RELEASE METHODOLOGY

Contract Number AFOSR-83-0333


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84 08 30 047

## ABSTRACT

The order release problem involves selecting subsets of available orders to release to the shop floor such that the system is utilized efficiently and queue time is reduced. A solution to this problem is proposed which combines Leontief flow models and linear programming in an iterative procedure. Examples of the approach are illustrated.

## INTRODUCTION

The development of manufacturing planning and control systems for timely and efficient production of aircraft and aircraft components will substantially increase the surge capacity of the aerospace industry. An important element of a manufacturing planning and control system is the order release policy, which controls when parts or subassemblies are released to the production floor or to a flexible manufacturing system for subsequent scheduling through that system.

Often there is some flexibility in determining when orders will be released to manufacturing. Order lead time is composed of estimated processing time, and allowances for queue time and travel time. If orders are to be processed in groups (such as nested sheet metal parts) a time allowance must be included for collection of similar orders and assignment to groups. In addition, the cmplexity of aircraft assemblies makes it advisable in many cases to include safety time to increase the probability that all orders are available when required for assembly. The non processing time components of lead time allow some flexibiity in scheduling: the pool of available orders may be divided into subsets which are then released at selected intervals to the shop floor. Careful selection of the subsets can alleviate production bottlenecks, thereby decreasing the average time required to complete an order.[1]

The order release problem has been largely ignored in the literature of production planning. Typically, a release strategy based on critical ratio (processing time divided by remaining time before order due date) is assumed.[2,3,4] This approach does not consider the effect of changes in product mix or work in process inventory on the performance of the production facility and thus may result in excessive resource competition

among orders and inability to achieve due dates. Critical ratio appears to be most successful in those operations with relatively stable product mix and production requirements.

A few researchers have studied the order release problem. Solberg[5] created a closed loop queueing model which predicts a production rate under steady-state conditions. Product mix and work in process inventory level may be varied until the desired results are obtained. The steady state assumption limits the usefulness of this model in the order release environment, where the time horizon is relatively short and product mix varies.

Irastorza and Deane[6] developed a mixed integer programming formulation for job release with the objective of balancing workload while meeting due dates. Although conceptually interesting, the utility of their approach is severely limited: the combinatorial nature of scheduling problems makes optimization infeasible for problems of realistic size.[7]

Another approach is required which does not encounter the severe combinatorial problems that occur in integer programming. The approach selected for this study was to formulate the problem using a Leontief Flow Model, combined with linear programming for optimization of load.

## THE LEONTIEF FLOW MODEL

One of the first applications of linear flow models was the economic model built by Leontief[8]. As the name implies, these models are based on a system of linear transfers from one sector to another. A sector is defined as a partition of the model which can receive units from another sector and/or send units to another sector. The model is defined by a set of linear equations which describe the transfer of units from sector to sector.

The units flowing through the model must be homogeneous such as dollars in the economy or in this case parts moving through a production environment. The equations are usually expressed in their matrix form as:

$X = AX + Y$

where,

$X$ = n x 1 vector containing the total demand on sector $x_n$

$A$ = n x n matrix containing the technical coefficients

$Y$ = n x 1 vector containing the initial input to sector $y_n$

The linear equations which make up the matrices have the following form.

$$x_i = a_{i1} x_1 + a_{i2} x_2 + \ldots + a_{in} x_n + y_i \qquad i=1,2\ldots n$$

where,

$x_i$ = total number of units passing through sector i

$a_{ij}$ = fraction of units in sector j which are transferred directly to sector i

$y_i$ = initial number of units input to sector i

The matrix equation shown above can be reduced further to obtain what is called the Leontief inverse.

$X = (I-A)^{-1}y$

where,

$I$ = identity matrix

The technical coefficient $a_{ij}$ from matrix A represents the direct demand of sector j on sector i or in other words the demand based on a one step transiton from j to i. This demand is simply the percentage of units transferred directly from j to i. An input of one unit into sector j will create a direct demand of $a_{ij}$ on sector i. Multiplying the initial input $y_j$

by the technical coefficient results in the total direct demand on sector i by sector j.

The coefficients in the Leontief inverse represent the total demand of sector j on sector i or the demand based on all possible transitions from j to i. A coefficient greater than one is an indication that the unit is transferred to that sector more than once. Summing the coefficients for any column provides the average number of transfers until a unit leaves the system given that it enters sector j.

The following example is used to illustrate the model. A total of three part types flow through a job shop containing three machines with routings as shown.

| Part Type | Routing |
|---|---|
| A | 1 --> 2 |
| B | 2 --> 3 |
| C | 3 --> 2 |

The initial loading of the parts is,

| Part Type | Initial Loading |
|---|---|
| A | 10 |
| B | 20 |
| C | 15 |

The transfer matrix representing the flow of parts from one machine to another is,

| | | From | |
|---|---|---|---|
| | 1 | 2 | 3 |
| 1 | | | |
| To 2 | 10 | | 15 |
| 3 | | 20 | |

The total demand on sector i is calculated by adding the initial input to all the transfers in row i. The technical coefficient matrix, A, is calculated by dividing the transfers in row i by the total demand, $x_i$.

This results in the following technical coefficient matrix.

| | 1 | 2 | 3 |
|---|---|---|---|
| 1 | | | |
| 2 | 1.000 | | 0.428 |
| 3 | | 0.444 | |

The Leontief matrix can then be calculated in a straightforward manner from the A matrix.

| | 1 | 2 | 3 |
|---|---|---|---|
| 1 | 1.000 | | |
| 2 | 1.235 | 0.235 | 0.529 |
| 3 | 0.549 | 0.549 | 1.235 |

The coefficients in the Leontief show the total demand of one unit entering machine n on the other machines.

The Leontief model is used to represent the workload on machines in the production facility. Sectors are defined as machines or work stations and the units being transferred are parts. From the initial demand for parts and the routing summary, the transfer matrix can be easily calculated. Performing the necessary calculations as described above results in the Leontief inverse which provides the total demand of part n on machine m.

This approach is particularly applicable to large, complex production systems, where direct optimization methods cannot be used. As the number of parts and number of routings increases, a better approximation of demand is achieved. In addition, rework of parts can be directly incorporated in the model without increasing its complexity.

The challenge in any order release strategy is to release the jobs in such a way as to provide high utilization of the machines and other resources. The Leontief model does not take into account the capacity of the machines. Linear programming is used in conjunction with the results of the Leontief model in order to introduce the capacity constraints as well as maximize utilization of the machines.

Multiplying the Leontief inverse coefficients by the operation time of part n at machine m provides a set of capacity requirements on machine m. These requirements can be used in an LP model with an objective function which minimizes unused capacity on the machines, or which maximizes the number of parts produced. The example below uses an objective function which minimizes the maximum machine idle time. No machine will have unused capacity greater than z time units.

minimize $Z = z$

subject: $z + c_{ji} Y_1 + C_{j2}Y_2 + \dots + C_{jn}Y_n = C_j$ for $j=1,\dots, m$

$y_i \leq D_i$ for $i=1, \dots, n$

where:

- $n$ = the number of parts
- $m$ = the number of machines
- $c_{ji}$ = the capacity requirements of part i on machine j
- $Y_i$ = the number of units of part i to release
- $D_i$ = demand for part i
- $C_j$ = available capacity on machine j

The first constraint contains the capacity requirements for machine j, and restricts the maximum idle time on any mahcine to z time units. At the same time the capacity used is limited by the available capacity, $C_j$. The last constraint insures that no more than the required number of parts are introduced into the system.

An alternative objective function would be to maximize the fraction of parts to be released. This function results in the following equation.

$f_1 Y_1 + f_2 Y_2 + \dots + f_n Y_n = Z$

where,

$f_n$ = 1/ Initial demand for Part n

One of the problems encountered with this equation was that the fraction of parts released from the LP solution was almost the same for each part while the utilization of machines was low.

Another possible objective function would be to maximize the average utilization of the machines. The objective function becomes:

minimize $\quad Z = z_1 + z_2 + \ldots + z_m$

subject to:

$$z_j + c_{j1} Y_1 + c_{j2} Y_2 + \ldots c_{jn} Y_n = C_j \quad \text{for } j=1, \ldots, m$$

$$Y_i \leq D_i \quad \text{for } i=1, \ldots, n$$

This objective maximizes average utilization by minimizing the sum of unused capacity on all machines. Note that minimizing the sum is equivalent to minimizing the average, since they differ by a constant factor for a fixed number of machines.

Other objective functions may be used. The choice of an objective will depend upon the requirements of the particular production system and the goals of the system managers.

At any period, selection of the orders to be released from the set of pending orders can be performed by a combination of the Leontief model with the LP model. Any work currently on the floor is constrained to be included in the LP solution by setting lower bounds on the values of $Y_i$ for the appropriate parts, and by creating an additional input sector for those parts.

An iterative procedure is used to select the orders to be released in each production period from the set of pending orders. First, the Leontief inverse is calculated using all the pending (not released) orders. The capacity requirements are then derived from the inverse and the LP is

formulated. The results of the LP provide the number of parts and part types to be released. A new Leontief inverse is calculated from these results and the LP is formulated again. This repetition continues until there is no change in the LP results.

The iterative procedure is required because the Leontief is an approximation of the capacity requirements across all part types. When a subset of parts is selected, the coefficients matrix will change to reflect the part mix chosen for release. In addition, by formulating the capacity problem as an LP, we are approximating the number of parts to release. The approximation is performed by rounding the fractional number of parts to the nearest integer. LP rather than IP was used because of reduced computational requirements, and because the Leontief is an approximation of the capacity required.

The last step is to calculate the actual capacity used by the parts from the LP solution. If there is any available capacity remaining, the procedure is repeated, excluding the selected set of part types from the Leontief model and LP formulation. The purpose of this last step is to utilize any remaining capacity.

EXAMPLE

The strategy is illustrated using the following example. Numbers in parentheses represent the operation times at each machine. The time frame in this example was broken down into 8 hour periods. All time units are expressed in hours.

| Part Type | Quantity | Routing (Operation Time) |
|---|---|---|
| A | 50 | 1(.2) --> 2(1.4) --> 3(1.0) |
| B | 15 | 5(.3) --> 4(.6) --> 1(.8) --> 3(.2) --> 1(.7) |
| C | 30 | 2(.2) --> 3(1.1) --> 2(.4) --> 1(.5) |
| D | 30 | 5(.7) --> 2(1.3) |
| E | 25 | 1(.3) --> 3(2.2) --> 2(1.0) --> 5(.1) |
| F | 60 | 2(.2) --> 5(.4) --> 4(.8) --> 2(.3) --> 5(.1) |
| G | 10 | 1(.7) --> 4(.2) --> 1(.6) --> 3(.8) |
| H | 15 | 3(.1) --> 4(.5) --> 1(.6) --> 3(.3) |
| I | 35 | 2(.9) --> 1(.5) --> 4(.6) --> 1(1.2) |
| J | 20 | 5(1.2) --> 1(1.5) --> 3(.7) --> 4(.2) --> 2(.8) |

The steps of the procedure for one period are shown in Figures 1-4. The objective function used was maximization of minimum machine or work center utilization. Four iterations were required to select the initial set of orders to release (Figures 1-3). Three part types were selected: F, H, and J.

At this point, utilized capacity is compared to available capacity and an attempt is made to allocate unused capacity among the parts which have not been selected for release. This is illustrated in Figure 4.

The Leontief model can be used on a period by period basis to release orders to the system. In an actual production facility, the work in process at the end of one time period could be used as input for the next time period. Any new orders arriving during the period could also be added to the input vector.

Here, we will assume that all orders input during a period would be completed during that period, thereby allowing the entire capacity of the facility to be available during the next period. Thus, a series of solutions can be produced, each representing one set of orders to release.

The original direction of this research involved using the results of the Leontief models in a continuous simulation model to predict bottlenecks and improve upon system flow. However, in the course of developing the Leontief model it became clear that a linear programming approach could be

used in conjunction with the linear flow model, and that a combination of the two would result in order release policies that did not exceed a stated capacity on any of the machines in the facility. Since the continuous model attempts to relieve bottlencks by moving excess work to other time periods, it is not applicable in the present environment. Therefore, efforts were concentrated on combining the Leontief model with linear programming rather than with a continuous simulation model.

## EVALUATION OF THE METHODOLOGY

Extensive effort is required to obtain an order release strategy for a single situation. This is because a potentially large number of iterations may be required to compute a single order release. This work was performed using an available LP code without customization, requiring a new problem to be constructed and solved for each iteration in the order selection procedure.

Because of time limitations, it was necessary to limit the testing to one randomly generated example of a medium sized problem. This testing is reported here.

Further work would depend on the development of a special purpose algorithm for this problem which combined the Leontief, LP, and iteration procedures into a single package.

The problem that was solved included 10 operations or machines and 25 order types, with randomly generated data. Each order type had 5 through 10 operations to be performed, with equal probability associated with each numer of operations in the permissable range. Operation times were generated from a uniform distribution with minimum .5 and maximum 1.5 time units. The number of pieces in each order was also randomly generated, and

adjusted such that no operation was assigned more than 160 time units of work. Data for the test problem is contained in Table 1.

The objective of the testing was to generate 4 order releases, each requiring no more than 40 units of work on the most heavily loaded machine. These releases were generated assuming that the work begun in one time period would be completed in that period. The order releases for each time period are shown in Table 2. The first three were computed using the proposed methodology, while the fourth consists of the remaining parts.

A simulation model of the system was constructed to determine the actual machine loadings and part throughput time acheived by this order release policy. The SIMAN [9] simulation language was used. Actual operation times were assumed equal to the estimated times, and orders were processed at each machine on a first in first out basis. The SIMAN program is included as Figure 5. Figure 6 contains summary reports which include average part flow time, machine utilization, and queue sizes for each order release period. Work left in the system at the end of one period is carried forward to the next period in the model. The statistics computed are average number in queue, average machine utilization, and order flow time for each release period. It was assumed that all parts of a single type released in one period would be processed as a batch. In addition, a fifth period was run to complete all work in process.

Results indicate a wide range in utilizations and small queue sizes during the first order release period. This is because the system is empty at the beginning of the period; typically there would be work in process on the floor. Periods 2 and 3 show higher machine utilization but correspondingly longer queues. During period 4, utilization and queue sizes drop as some operations are completed. Finally, the fifth period exhibits

lower utilization and small queues as the final parts are removed from the system.

These preliminary results indicate a reasonable order release strategy; further testing is required before definitive results are available.

FURTHER RESEARCH

Several open research questions remain. Further algorithm development is required. The number of iterations varies substantially from one run to another; it is not always clear how to determine a stopping point, particularly because it is possible for cycling behavior to occur. In addition, it may be possible to develop a heuristic which substantially reduces the computational effort by directing the iterative procedure along the direction of greatest improvement.

Research effort is required to develop a method of optimizing over several periods rather than on a period by period basis. This will depend upon having a unified procedure which combines the Leontief, LP, and iteration into one software package.

# PROBLEM 1

| Order | # Pieces | Routing (Time) | | | | |
|---|---|---|---|---|---|---|
| 1 | 4 | 3 (1.1) | 10 (1.1) | 6 (1.4) | 8 (1.1) | 9 (1.0) |
| | | 10 (1.0) | 8 (1.4) | 9 (1.4) | 8 (0.7) | |
| 2 | 4 | 4 (1.1) | 3 (0.8) | 6 (1.0) | 3 (1.4) | 4 (1.4) |
| | | 2 (1.2) | 6 (0.6) | 2 (1.0) | 4 (0.5) | |
| 3 | 12 | 9 (0.6) | 2 (1.4) | 8 (1.1) | 2 (1.3) | 1 (0.8) |
| 4 | 6 | 6 (0.6) | 2 (0.5) | 5 (0.6) | 10 (1.3) | 7 (1.1) |
| | | 2 (1.2) | | | | |
| 5 | 17 | 5 (0.9) | 2 (0.6) | 6 (0.6) | 3 (0.8) | 9 (0.5) |
| | | 2 (0.8) | 1 (0.9) | | | |
| 6 | 13 | 3 (0.9) | 1 (1.2) | 7 (1.2) | 3 (0.6) | 6 (1.2) |
| 7 | 15 | 3 (0.9) | 7 (0.7) | 4 (0.8) | 10 (1.1) | 5 (1.4) |
| 8 | 12 | 6 (1.2) | 10 (0.7) | 1 (0.5) | 3 (1.4) | 9 (1.4) |
| | | 4 (0.6) | | | | |
| 9 | 10 | 1 (0.6) | 8 (0.9) | 2 (1.1) | 9 (0.8) | 8 (1.5) |
| | | 9 (1.4) | 3 (1.0) | 7 (0.9) | 3 (1.3) | |
| 10 | 12 | 9 (1.4) | 6 (0.7) | 7 (1.0) | 9 (1.4) | 5 (0.5) |
| 11 | 4 | 2 (1.4) | 4 (0.7) | 10 (0.6) | 2 (1.0) | 5 (0.7) |
| | | 2 (0.6) | 4 (0.6) | 1 (1.4) | | |
| 12 | 5 | 7 (0.6) | 4 (0.6) | 7 (0.9) | 8 (1.0) | 4 (0.7) |
| | | 6 (1.5) | 3 (1.4) | 5 (1.2) | | |
| 13 | 7 | 7 (0.6) | 6 (0.8) | 1 (0.9) | 9 (0.5) | 8 (0.8) |
| | | 9 (0.8) | 1 (1.4) | 6 (0.9) | 1 (0.9) | |

Table 1. Test Data

Problem 1, continued

| Order | # Pieces | Routing (Time) | | | | |
|---|---|---|---|---|---|---|
| 14 | 9 | 9 (0.6) | 6 (0.6) | 7 (1.2) | 4 (1.1) | 3 (1.2) |
| | | 1 (1.3) | 8 (1.4) | 5 (0.8) | | |
| 15 | 1 | 2 (1.0) | 7 (1.1) | 5 (1.1) | 2 (1.3) | 6 (0.7) |
| | | 5 (0.8) | 8 (1.0) | 6 (1.5) | | |
| 16 | 2 | 6 (1.2) | 7 (0.8) | 10 (1.1) | 8 (1.4) | 3 (1.2) |
| | | 4 (1.4) | 2 (1.5) | 9 (1.1) | 4 (1.0) | 8 (1.1) |
| 17 | 4 | 10 (1.3) | 6 (1.0) | 9 (1.4) | 7 (1.2) | 6 (1.4) |
| | | 7 (1.1) | 9 (1.4) | 2 (1.2) | 8 (0.9) | 9 (1.5) |
| 18 | 4 | 10 (0.9) | 4 (1.1) | 1 (1.2) | 10 (0.6) | 5 (1.2) |
| | | 4 (1.2) | 1 (0.8) | 2 (0.5) | | |
| 19 | 2 | 6 (1.1) | 5 (1.3) | 7 (1.3) | 9 (0.8) | 3(1.2) |
| | | 8 (1.5) | | | | |
| 20 | 7 | 4 (0.8) | 6 (1.2) | 5 (0.6) | 10 (0.9) | 4 (1.2) |
| 21 | 3 | 10 (0.6) | 3 (1.4) | 1 (0.9) | 3 (0.9) | 5 (1.2) |
| | | 6 (1.2) | | | | |
| 22 | 4 | 9 (1.1) | 3 (0.6) | 4 (0.8) | 10 (1.0) | 6 (1.1) |
| | | 5 (0.5) | | | | |
| 23 | 9 | 5 (0.5) | 7 (1.3) | 10 (1.2) | 6 (1.5) | 4 (0.6) |
| | | 10 (0.7) | 1 (0.8) | 10 (0.8) | 9 (0.8) | |
| 24 | 7 | 2 (0.6) | 4 (0.8) | 3 (0.6) | 7 (1.3) | 10 (0.5) |
| | | 4 (1.2) | 7 (0.8) | | | |
| 25 | 16 | 4 (1.5) | 2 (0.8) | 1 (0.6) | 5 (0.6) | 10 (0.8) |
| | | 5 (0.9) | 2 (0.7) | 7 (1.0) | 9 (0.9) | |

Machine loads:

| | | | |
|---|---|---|---|
| 1 | 119.6 | 6 | 135.1 |
| 2 | 139.0 | 7 | 132.7 |
| 3 | 134.6 | 8 | 87.0 |
| 4 | 126.9 | 9 | 159.5 |
| 5 | 111.7 | 10 | 110.2 |

Table 1 (continued)

| Period 1 | | Period 2 | | Period 3 | | Period 4 | |
|---|---|---|---|---|---|---|---|
| Order | # Pieces | Order | # Pieces | Order | # Pieces | Order | # Pieces |
| 1 | 3 | 1 | 1 | 2 | 1 | 2 | 3 |
| 4 | 2 | 4 | 3 | 3 | 3 | 3 | 9 |
| 5 | 11 | 6 | 3 | 4 | 1 | 5 | 1 |
| 9 | 6 | 7 | 12 | 5 | 5 | 6 | 4 |
| 12 | 4 | 8 | 3 | 6 | 6 | 8 | 3 |
| 14 | 4 | 9 | 3 | 7 | 3 | 10 | 10 |
| 15 | 1 | 11 | 4 | 8 | 6 | 13 | 1 |
| 20 | 7 | 13 | 4 | 9 | 1 | 14 | 2 |
| 23 | 9 | 16 | 1 | 10 | 2 | 22 | 2 |
| 24 | 5 | 17 | 3 | 12 | 1 | 25 | 2 |
| | | 18 | 1 | 13 | 2 | | |
| | | 19 | 2 | 14 | 3 | | |
| | | 21 | 2 | 16 | 1 | | |
| | | 25 | 8 | 17 | 1 | | |
| | | | | 18 | 3 | | |
| | | | | 21 | 1 | | |
| | | | | 22 | 2 | | |
| | | | | 24 | 2 | | |
| | | | | 25 | 6 | | |

Table 2 Order Releases

Technical Coefficient Matrix

| | A | B | C | D | E | F | G | H | I | J | 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| A | | | | | | | | | | | | | | | |
| B | | | | | | | | | | | | | | | |
| C | | | | | | | | | | | | | | | |
| D | | | | | | | | | | | | | | | |
| E | | | | | | | | | | | | | | | |
| F | | | | | | | | | | | | | | | |
| G | | | | | | | | | | | | | | | |
| H | | | | | | | | | | | | | | | |
| I | | | | | | | | | | | | | | | |
| J | | | | | | | | | | | | | | | |
| 1 | 1.000 | | | | 1.000 | | 1.000 | | | | | 0.191 | 0.083 | 0.483 | 0.095 |
| 2 | | | 1.000 | | | 1.000 | | | 1.000 | | 0.192 | | 0.305 | 0.516 | 0.142 |
| 3 | | | | | | | | 1.000 | | | 0.326 | 0.235 | | | |
| 4 | | | | | | | | | | | 0.173 | | 0.194 | | 0.357 |
| 5 | | 1.000 | | 1.000 | | | | | | 1.000 | | 0.426 | | | |

Figure 1. Order Release (Iteration 1)

Leontief Inverse

| | A | B | C | D | E | F | G | H | I | J | 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| A | 1.000 | | | | | | | | | | | | | | |
| B | | 1.000 | | | | | | | | | | | | | |
| C | | | 1.000 | | | | | | | | | | | | |
| D | | | | 1.000 | | | | | | | | | | | |
| E | | | | | 1.000 | | | | | | | | | | |
| F | | | | | | 1.000 | | | | | | | | | |
| G | | | | | | | 1.000 | | | | | | | | |
| H | | | | | | | | 1.000 | | | | | | | |
| I | | | | | | | | | 1.000 | | | | | | |
| J | | | | | | | | | | 1.000 | | | | | |
| 1 | 1.492 | 0.621 | 0.677 | 0.621 | 1.492 | 0.677 | 1.492 | 0.539 | 0.677 | 0.621 | 1.492 | 0.677 | 0.539 | 1.071 | 0.621 |
| 2 | 0.808 | 0.764 | 1.674 | 0.764 | 0.808 | 1.674 | 0.808 | 0.822 | 1.674 | 0.764 | 0.808 | 1.674 | 0.822 | 1.255 | 0.764 |
| 3 | 0.677 | 0.383 | 0.615 | 0.383 | 0.677 | 0.615 | 0.677 | 1.370 | 0.615 | 0.383 | 0.677 | 0.615 | 1.370 | 0.645 | 0.383 |
| 4 | 0.513 | 0.655 | 0.491 | 0.655 | 0.513 | 0.491 | 0.513 | 0.485 | 0.491 | 0.655 | 0.513 | 0.491 | 0.485 | 1.502 | 0.655 |
| 5 | 0.344 | 1.325 | 0.713 | 1.325 | 0.344 | 0.713 | 0.344 | 0.350 | 0.713 | 1.325 | 0.344 | 0.713 | 0.350 | 0.535 | 1.325 |

Figure 1 (continued)

**Capacity Requirements**

| | A | B | C | D | E | F | G | H | I | J |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 0.298 | 0.932 | 0.338 | | 0.447 | | 1.939 | 0.323 | 1.151 | 0.932 |
| 2 | 1.131 | | 1.004 | 0.993 | 0.808 | 0.837 | | | 1.506 | 0.611 |
| 3 | 0.677 | 0.076 | 0.676 | | 1.491 | | 0.542 | 0.548 | | 0.268 |
| 4 | | 0.393 | | | | 0.393 | 0.102 | 0.242 | 0.295 | 0.131 |
| 5 | | 0.397 | | 0.928 | 0.103 | 0.356 | | | | 1.591 |

Results from the LP Model

| Part Type | Number to Release |
|---|---|
| B | 2 |
| F | 8 |
| H | 13 |
| J | 2 |

Figure 1 (continued)

Technical Coefficient Matrix

| | A | B | C | D | E | F | G | H | I | J | 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| A | | | | | | | | | | | | | | | |
| B | | | | | | | | | | | | | | | |
| C | | | | | | | | | | | | | | | |
| D | | | | | | | | | | | | | | | |
| E | | | | | | | | | | | | | | | |
| F | | | | | | | | | | | | | | | |
| G | | | | | | | | | | | | | | | |
| H | | | | | | | | | | | | | | | |
| I | | | | | | | | | | | | | | | |
| J | | | | | | | | | | | | | | | |
| 1 | | | | | | | | | | | | | 0.066 | 0.599 | 0.099 |
| 2 | | | | | | 1.000 | | | | | | | | 0.399 | |
| 3 | | | | | | | | 1.000 | | | 0.894 | | | | |
| 4 | | | | | | | | | | | | | 0.500 | | 0.500 |
| 5 | | 1.000 | | | | | | | | 1.000 | | 0.888 | | | |

Figure 2. Order Release (Iteration 2)

**Leontief Inverse**

| | A | B | C | D | E | F | G | H | I | J | 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| A | 1.000 | | | | | | | | | | | | | | |
| B | | 1.000 | | | | | | | | | | | | | |
| C | | | 1.000 | | | | | | | | | | | | |
| D | | | | 1.000 | | | | | | | | | | | |
| E | | | | | 1.000 | | | | | | | | | | |
| F | | | | | | 1.000 | | | | | | | | | |
| G | | | | | | | 1.000 | | | | | | | | |
| H | | | | | | | | 1.000 | | | | | | | |
| I | | | | | | | | | 1.000 | | | | | | |
| J | | | | | | | | | | 1.000 | | | | | |
| 1 | | 0.818 | | | | 0.727 | | 0.762 | | 0.818 | 1.681 | 0.727 | 0.762 | 1.300 | 0.818 |
| 2 | | 0.421 | | | | 1.374 | | 0.409 | | 0.421 | 0.368 | 1.374 | 0.409 | 0.769 | 0.421 |
| 3 | | 0.732 | | | | 0.650 | | 1.681 | | 0.732 | 1.504 | 0.850 | 1.881 | 1.183 | 0.732 |
| 4 | | 1.053 | | | | 0.936 | | 1.022 | | 1.053 | 0.915 | 0.936 | 1.022 | 1.923 | 1.053 |
| 5 | | 1.374 | | | | 1.221 | | 0.363 | | 1.374 | 0.325 | 1.221 | 0.363 | 0.683 | 1.374 |

Figure 2 (continued)

**Capacity Requirements**

| | A | B | C | D | E | F | G | H | I | J |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | | 1.227 | | | | | | 0.457 | | 1.227 |
| 2 | | | | | | 0.687 | | | | 0.337 |
| 3 | | 0.146 | | | | | | 0.672 | | 0.512 |
| 4 | | 0.631 | | | | 0.749 | | 0.511 | | 0.210 |
| 5 | | 0.412 | | | | 0.610 | | | | 1.649 |

Results from the LP Model

| Part Type | Number to Release |
|---|---|
| F | 6 |
| H | 6 |
| J | 3 |

Figure 2 (continued)

**Iteration 3**

**Capacity Requirements**

| | A | B | C | D | E | F | G | H | I | J |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | | | | | | | | 0.349 | | 1.057 |
| 2 | | | | | | 0.744 | | | | 0.489 |
| 3 | | | | | | | | 0.633 | | 0.493 |
| 4 | | | | | | 0.652 | | 0.587 | | 0.203 |
| 5 | | | | | | 0.595 | | | | 1.786 |

Results from the LP Model

| Part Type | Number to Release |
|---|---|
| F | 5 |
| H | 7 |
| J | 3 |

Iteration 4

Capacity Requirements

| | A | B | C | D | E | F | G | H | I | J |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | | | | | | | | 0.386 | | 1.201 |
| 2 | | | | | | 0.708 | | | | 0.433 |
| 3 | | | | | | | | 0.657 | | 0.560 |
| 4 | | | | | | 0.625 | | 0.574 | | 0.203 |
| 5 | | | | | | 0.544 | | | | 1.700 |

Results from the LP Model

| Part Type | Number to Release |
|---|---|
| F | 6 |
| H | 6 |
| J | 3 |

Figure 3. Order Release (Iterations 3-4)

| Part Type | Machine 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|---|
| F | | 3.0 | | 4.8 | 3.0 |
| H | 2.4 | | 2.4 | 2.0 | |
| J | 4.5 | 2.4 | 2.1 | 0.6 | 3.6 |
| Total Capacity Used | 6.9 | 5.4 | 4.5 | 7.4 | 6.6 |
| Available Capacity | 1.1 | 2.6 | 3.5 | 0.6 | 1.6 |

a. Capacity Requirements

| | A | B | C | D | E | G | I |
|---|---|---|---|---|---|---|---|
| 1 | .326 | 1.062 | 0.418 | | 0.490 | 2.123 | 1.420 |
| 2 | 0.930 | | 0.926 | 1.091 | 0.664 | | 1.460 |
| 3 | 0.628 | 0.098 | 0.920 | | 1.383 | 0.503 | |
| 4 | | 0.227 | | | | 0.689 | 0.126 |
| 5 | | 0.331 | | | 0.773 | 0.025 | |

b. Results from the LP Model

| Additional Part Types | Number to Release |
|---|---|
| E | 1 |

Figure 4. Utilizing Excess Capacity

```
SIMAN MODEL PROCESSOR RELEASE 2.0
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      BEGIN;
  10             STATION,12:MARK(3);                 initial input station
  20             ROUTE:0,SEQ;                        route to first operation
      ;
  30             STATION,1-10;                       operations
  40             QUEUE,M;                            wait for the machine
  50             SEIZE:MACHINE(M);                   on the machine
  60             DELAY:A(1)*A(2);                    process the batch
  70             RELEASE:MACHINE(M);                 done with machine
  80             ROUTE:0,SEQ;                        send to next operation
      ;
  90             STATION,11;                         output station
 100             TALLY:1,INT(3):DISPOSE;             collect statistics
      END;
```

```
      SUBROUTINE PRIME
      DIMENSION NUM(25)
C
C   READ IN NUMBER OF ORDERS FOR THE WEEK
C
      READ(1,*) NUM
C
C   RELEASE ORDERS TO THE SYSTEM
C
      DO 100 I=1,25
         IF(NUM(I) .EQ. 0) GO TO 100
         CALL CREATE(JOB)
         VAL=NUM(I)
         CALL SETA(JOB,2,VAL)
         CALL SETNS(JOB,I)
         CALL ENTER(JOB,12)
100   CONTINUE
      RETURN
      END
```

Figure 5. Simulation Model

```
SIMAN EXPERIMENT PROCESSOR RELEASE 2.0
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    BEGIN;
 10 PROJECT,ORDER RELEASE,MEDEIROS,6/30/1984;
 20 DISCRETE,50,3,10,12;
 30 DSTAT:1,NQ(1),WAIT 1:
          2,NQ(2),WAIT 2:
          3,NQ(3),WAIT 3:
          4,NQ(4),WAIT 4:
          5,NQ(5),WAIT 5:
          6,NQ(6),WAIT 6:
          7,NQ(7),WAIT 7:
          8,NQ(8),WAIT 8:
          9,NQ(9),WAIT 9:
          10,NQ(10),WAIT 10:
          11,NR(1),UTIL. 1:
          12,NR(2),UTIL. 2:
          13,NR(3),UTIL. 3:
          14,NR(4),UTIL. 4:
          15,NR(5),UTIL. 5:
          16,NR(6),UTIL. 6:
          17,NR(7),UTIL. 7:
          18,NR(8),UTIL. 8:
          19,NR(9),UTIL. 9:
          20,NR(10),UTIL. 10;
 40 REPLICATE,4,0,40,NO;
 50 RESOURCES:1-10,MACHINE;
 60 TALLIES:1,FLOWTIME;
 70 SEQUENCES.1,3,1.1/10,1.1/6,1.4/8,1.1/9,1.0/10,1.0/8,1.4/9,1.4/8,.7/11:
               2,4,1.1/3,0.8/6,1.0/3,1.4/4,1.4/2,1.2/6,0.6/2,1.0/4,0.5/11:
               3,9,.6/2,1.4/3,1.1/2,1.3/1,.8/11:
               4,6,.6/2,.5/5,.6/10,1.3/7,1.1/11:
               5,5,.9/2,.6/6,.6/3,.8/9,.5/11:
               6,3,.9/1,1.2/7,1.2/3,.6/6,1.2/11:
               7,3,.9/7,.7/4,.8/10,1.1/5,1.4/11:
               8,6,1.2/10,.7/1,.5/3,1.4/9,1.4/4,.6/11:
               9,1,.6/8,.9/2,1.1/9,.8/8,1.5/9,1.4/3,1./7,.9/3,1.3/11:
              10,9,1.4/6,.7/7,1./9,1.4/5,.5/11:
              11,2,1.4/4,.7/10,.6/2,1./5,.7/2,.6/4,.6/1,1.4/11:
              12,7,.6/4,.6/7,.9/8,1./4,.7/6,1.5/3,1.4/5,1.2/11:
              13,7,.6/6,.8/1,.9/9,.5/8,.8/9,.8/1,1.4/6,.9/1,.9/11:
              14,9,.6/6,.6/7,1.2/4,1.1/3,1.2/1,1.3/8,1.4/5,.8/11:
              15,2,1./7,1.1/5,1.1/2,1.3/6,.7/5,.8/3,1./6,1.5/11:
              16,6,1.2/7,.8/10,1.1/8,1.4/3,1.2/4,1.4/2,1.5/9,1.1/4,1./8,1.1/1
              17,10,1.3/6,1./9,1.4/7,1.2/6,1.4/7,1.1/9,1.4/2,1.2/8,.9/9,1.5/1
              18,10,.9/4,1.1/1,1.2/10,.6/5,1.2/4,1.2/1,.8/2,.5/11:
              19,6,1.1/5,1.3/7,1.3/9,.8/3,1.2/8,1.5/11:
              20,4,.8/6,1.2/5,.6/10,.9/4,1.2/11:
              21,10,.6/3,1.4/1,.9/3,.9/5,1.2/6,1.2/11:
              22,9,1.1/3,.6/4,.8/10,1./6,1.1/5,.5/11:
              23,5,.5/7,1.3/10,1.2/6,1.5/4,.6/10,.7/1,.8/10,.8/9,.8/11:
              24,2,.6/4,.8/3,.6/7,1.3/10,.5/4,1.2/7,.8/11:
              25,4,1.5/2,.8/1,.6/5,.6/10,.8/5,.9/2,.7/7,1./9,.9/11;
    END;
```

**Figure 5. (Continued)**

SIMAN RUN PROCESSOR RELEASE 2.0


SIMAN SUMMARY REPORT

RUN NUMBER 1 OF 5

PROJECT: ORDER RELEASE
ANALYST: MEDEIROS
DATE : 6/30/1984

RUN ENDED AT TIME : 0.4000E+02

TALLY VARIABLES

| NUMBER | IDENTIFIER | AVERAGE | STANDARD DEVIATION | MINIMUM VALUE | MAXIMUM VALUE | NUMBER OF OBS. |
|---|---|---|---|---|---|---|
| 1 | FLOWTIME | 33.90000 | 0.00000 | 33.90000 | 33.90000 | 1 |

DISCRETE CHANGE VARIABLES

| NUMBER | IDENTIFIER | AVERAGE | STANDARD DEVIATION | MINIMUM VALUE | MAXIMUM VALUE | TIME PERIOD |
|---|---|---|---|---|---|---|
| 1 | WAIT 1 | 0.00000 | 0.00000 | 0.00000 | 0.00000 | 40.00 |
| 2 | WAIT 2 | 0.31250 | 0.55213 | 0.00000 | 2.00000 | 40.00 |
| 3 | WAIT 3 | 0.06750 | 0.25089 | 0.00000 | 1.00000 | 40.00 |
| 4 | WAIT 4 | 0.25500 | 0.56566 | 0.00000 | 2.00000 | 40.00 |
| 5 | WAIT 5 | 0.67750 | 0.88515 | 0.00000 | 3.00000 | 40.00 |
| 6 | WAIT 6 | 0.51000 | 0.62040 | 0.00000 | 2.00000 | 40.00 |
| 7 | WAIT 7 | 1.24750 | 1.04223 | 0.00000 | 3.00000 | 40.00 |
| 8 | WAIT 8 | 0.30750 | 0.47217 | 0.00000 | 2.00000 | 40.00 |
| 9 | WAIT 9 | 0.00000 | 0.00000 | 0.00000 | 0.00000 | 40.00 |
| 10 | WAIT 10 | 0.67250 | 0.79072 | 0.00000 | 2.00000 | 40.00 |
| 11 | UTIL. 1 | 0.22000 | 0.41425 | 0.00000 | 1.00000 | 40.00 |
| 12 | UTIL. 2 | 0.48750 | 0.49984 | 0.00000 | 1.00000 | 40.00 |
| 13 | UTIL. 3 | 0.50750 | 0.49994 | 0.00000 | 1.00000 | 40.00 |
| 14 | UTIL. 4 | 0.54750 | 0.49774 | 0.00000 | 1.00000 | 40.00 |
| 15 | UTIL. 5 | 0.54250 | 0.49819 | 0.00000 | 1.00000 | 40.00 |
| 16 | UTIL. 6 | 0.85000 | 0.35707 | 0.00000 | 1.00000 | 40.00 |
| 17 | UTIL. 7 | 0.80750 | 0.39426 | 0.00000 | 1.00000 | 40.00 |
| 18 | UTIL. 8 | 0.66750 | 0.47111 | 0.00000 | 1.00000 | 40.00 |
| 19 | UTIL. 9 | 0.47500 | 0.49937 | 0.00000 | 1.00000 | 40.00 |
| 20 | UTIL. 10 | 0.69250 | 0.46146 | 0.00000 | 1.00000 | 40.00 |

Figure 6. Simulation Output

SIMAN SUMMARY REPORT

RUN NUMBER 2 OF 5

PROJECT: ORDER RELEASE
ANALYST: MEDEIROS
DATE : 6/30/1984

RUN ENDED AT TIME : 0.8000E+02

TALLY VARIABLES

| NUMBER | IDENTIFIER | AVERAGE | STANDARD DEVIATION | MINIMUM VALUE | MAXIMUM VALUE | NUMBER OF OBS. |
|---|---|---|---|---|---|---|
| 1 | FLOWTIME | 56.98750 | 14.78092 | 44.50000 | 76.40000 | 8 |

DISCRETE CHANGE VARIABLES

| NUMBER | IDENTIFIER | AVERAGE | STANDARD DEVIATION | MINIMUM VALUE | MAXIMUM VALUE | TIME PERIOD |
|---|---|---|---|---|---|---|
| 1 | WAIT 1 | 0.66500 | 0.93422 | 0.00000 | 3.00000 | 40.00 |
| 2 | WAIT 2 | 0.12000 | 0.32496 | 0.00000 | 1.00000 | 40.00 |
| 3 | WAIT 3 | 4.44000 | 0.98559 | 0.00000 | 6.00000 | 40.00 |
| 4 | WAIT 4 | 2.41250 | 1.51405 | 0.00000 | 5.00000 | 40.00 |
| 5 | WAIT 5 | 0.00000 | 0.00000 | 0.00000 | 0.00000 | 40.00 |
| 6 | WAIT 6 | 2.47250 | 2.44729 | 0.00000 | 7.00000 | 40.00 |
| 7 | WAIT 7 | 0.54250 | 0.71986 | 0.00000 | 2.00000 | 40.00 |
| 8 | WAIT 8 | 0.24250 | 0.42860 | 0.00000 | 1.00000 | 40.00 |
| 9 | WAIT 9 | 0.16000 | 0.46840 | 0.00000 | 2.00000 | 40.00 |
| 10 | WAIT 10 | 0.56250 | 0.97267 | 0.00000 | 3.00000 | 40.00 |
| 11 | UTIL. 1 | 0.51750 | 0.49969 | 0.00000 | 1.00000 | 40.00 |
| 12 | UTIL. 2 | 0.42000 | 0.49356 | 0.00000 | 1.00000 | 40.00 |
| 13 | UTIL. 3 | 1.00000 | 0.00000 | 1.00000 | 1.00000 | 40.00 |
| 14 | UTIL. 4 | 1.00000 | 0.00000 | 1.00000 | 1.00000 | 40.00 |
| 15 | UTIL. 5 | 0.43000 | 0.49508 | 0.00000 | 1.00000 | 40.00 |
| 16 | UTIL. 6 | 0.73500 | 0.44133 | 0.00000 | 1.00000 | 40.00 |
| 17 | UTIL. 7 | 0.83250 | 0.37342 | 0.00000 | 1.00000 | 40.00 |
| 18 | UTIL. 8 | 0.55500 | 0.49697 | 0.00000 | 1.00000 | 40.00 |
| 19 | UTIL. 9 | 0.69750 | 0.45934 | 0.00000 | 1.00000 | 40.00 |
| 20 | UTIL. 10 | 0.59250 | 0.49137 | 0.00000 | 1.00000 | 40.00 |

Figure 6. (Continued)

SIMAN SUMMARY REPORT

RUN NUMBER 3 OF 5

PROJECT: ORDER RELEASE
ANALYST: MEDEIROS
DATE : 6/30/1984

RUN ENDED AT TIME : 0.1200E+03

TALLY VARIABLES

| NUMBER | IDENTIFIER | AVERAGE | STANDARD DEVIATION | MINIMUM VALUE | MAXIMUM VALUE | NUMBER OF OBS. |
|---|---|---|---|---|---|---|
| 1 | FLOWTIME | 57.94616 | 16.67029 | 25.10001 | 74.20000 | 13 |

DISCRETE CHANGE VARIABLES

| NUMBER | IDENTIFIER | AVERAGE | STANDARD DEVIATION | MINIMUM VALUE | MAXIMUM VALUE | TIME PERIOD |
|---|---|---|---|---|---|---|
| 1 | WAIT 1 | 2.17500 | 1.81228 | 0.00000 | 6.00000 | 40.00 |
| 2 | WAIT 2 | 1.73000 | 1.47380 | 0.00000 | 5.00000 | 40.00 |
| 3 | WAIT 3 | 3.70000 | 1.31529 | 1.00000 | 6.00000 | 40.00 |
| 4 | WAIT 4 | 3.14250 | 1.73413 | 0.00000 | 6.00000 | 40.00 |
| 5 | WAIT 5 | 0.39500 | 0.56919 | 0.00000 | 2.00000 | 40.00 |
| 6 | WAIT 6 | 2.22000 | 1.66631 | 0.00000 | 5.00000 | 40.00 |
| 7 | WAIT 7 | 1.21250 | 1.08275 | 0.00000 | 4.00000 | 40.00 |
| 8 | WAIT 8 | 0.06750 | 0.25089 | 0.00000 | 1.00000 | 40.00 |
| 9 | WAIT 9 | 1.47500 | 1.25275 | 0.00000 | 4.00000 | 40.00 |
| 10 | WAIT 10 | 4.13750 | 0.77369 | 2.00000 | 6.00000 | 40.00 |
| 11 | UTIL. 1 | 0.86750 | 0.33903 | 0.00000 | 1.00000 | 40.00 |
| 12 | UTIL. 2 | 0.93750 | 0.24206 | 0.00000 | 1.00000 | 40.00 |
| 13 | UTIL. 3 | 1.00000 | 0.00000 | 1.00000 | 1.00000 | 40.00 |
| 14 | UTIL. 4 | 0.88500 | 0.31902 | 0.00000 | 1.00000 | 40.00 |
| 15 | UTIL. 5 | 0.84750 | 0.35951 | 0.00000 | 1.00000 | 40.00 |
| 16 | UTIL. 6 | 0.82500 | 0.37997 | 0.00000 | 1.00000 | 40.00 |
| 17 | UTIL. 7 | 0.79750 | 0.40186 | 0.00000 | 1.00000 | 40.00 |
| 18 | UTIL. 8 | 0.43000 | 0.49508 | 0.00000 | 1.00000 | 40.00 |
| 19 | UTIL. 9 | 0.98750 | 0.11110 | 0.00000 | 1.00000 | 40.00 |
| 20 | UTIL. 10 | 1.00000 | 0.00000 | 1.00000 | 1.00000 | 40.00 |

Figure 6. (Continued)

SIMAN SUMMARY REPORT

RUN NUMBER 4 OF 5

PROJECT: ORDER RELEASE
ANALYST: MEDEIROS
DATE : 6/30/1984

RUN ENDED AT TIME : 0.1600E+03

TALLY VARIABLES

| NUMBER | IDENTIFIER | AVERAGE | STANDARD DEVIATION | MINIMUM VALUE | MAXIMUM VALUE | NUMBER OF OBS. |
|---|---|---|---|---|---|---|
| 1 | FLOWTIME | 63.15263 | 24.02509 | 28.30000 | 123.19999 | 19 |

DISCRETE CHANGE VARIABLES

| NUMBER | IDENTIFIER | AVERAGE | STANDARD DEVIATION | MINIMUM VALUE | MAXIMUM VALUE | TIME PERIOD |
|---|---|---|---|---|---|---|
| 1 | WAIT 1 | 2.10750 | 1.64953 | 0.00000 | 5.00000 | 40.00 |
| 2 | WAIT 2 | 0.89500 | 1.35425 | 0.00000 | 4.00000 | 40.00 |
| 3 | WAIT 3 | 1.36000 | 1.20017 | 0.00000 | 4.00000 | 40.00 |
| 4 | WAIT 4 | 0.33750 | 0.61935 | 0.00000 | 2.00000 | 40.00 |
| 5 | WAIT 5 | 1.71750 | 1.46721 | 0.00000 | 5.00000 | 40.00 |
| 6 | WAIT 6 | 1.61250 | 1.97923 | 0.00000 | 6.00000 | 40.00 |
| 7 | WAIT 7 | 0.75750 | 1.37974 | 0.00000 | 4.00000 | 40.00 |
| 8 | WAIT 8 | 0.00000 | 0.00000 | 0.00000 | 0.00000 | 40.00 |
| 9 | WAIT 9 | 3.89750 | 0.66858 | 0.00000 | 5.00000 | 40.00 |
| 10 | WAIT 10 | 0.59500 | 1.00796 | 0.00000 | 3.00000 | 40.00 |
| 11 | UTIL. 1 | 0.76750 | 0.42243 | 0.00000 | 1.00000 | 40.00 |
| 12 | UTIL. 2 | 0.49000 | 0.49990 | 0.00000 | 1.00000 | 40.00 |
| 13 | UTIL. 3 | 0.88500 | 0.31902 | 0.00000 | 1.00000 | 40.00 |
| 14 | UTIL. 4 | 0.58000 | 0.49356 | 0.00000 | 1.00000 | 40.00 |
| 15 | UTIL. 5 | 0.79250 | 0.40552 | 0.00000 | 1.00000 | 40.00 |
| 16 | UTIL. 6 | 0.83750 | 0.36891 | 0.00000 | 1.00000 | 40.00 |
| 17 | UTIL. 7 | 0.70750 | 0.45491 | 0.00000 | 1.00000 | 40.00 |
| 18 | UTIL. 8 | 0.20250 | 0.40186 | 0.00000 | 1.00000 | 40.00 |
| 19 | UTIL. 9 | 1.00000 | 0.00000 | 1.00000 | 1.00000 | 40.00 |
| 20 | UTIL. 10 | 0.45500 | 0.49797 | 0.00000 | 1.00000 | 40.00 |

Figure 6. (Continued)

SIMAN SUMMARY REPORT

RUN NUMBER 5 OF 5

PROJECT: ORDER RELEASE
ANALYST: MEDEIROS
DATE : 6/30/1984

RUN ENDED AT TIME : 0.1965E+03

TALLY VARIABLES

| NUMBER | IDENTIFIER | AVERAGE | STANDARD DEVIATION | MINIMUM VALUE | MAXIMUM VALUE | NUMBER OF OBS. |
|---|---|---|---|---|---|---|
| 1 | FLOWTIME | 72.48332 | 20.12101 | 42.69997 | 112.79997 | 12 |

DISCRETE CHANGE VARIABLES

| NUMBER | IDENTIFIER | AVERAGE | STANDARD DEVIATION | MINIMUM VALUE | MAXIMUM VALUE | TIME PERIOD |
|---|---|---|---|---|---|---|
| 1 | WAIT 1 | 0.05480 | 0.22758 | 0.00000 | 1.00000 | 36.50 |
| 2 | WAIT 2 | 0.51233 | 1.09444 | 0.00000 | 4.00000 | 36.50 |
| 3 | WAIT 3 | 0.00000 | 0.00000 | 0.00000 | 0.00000 | 36.50 |
| 4 | WAIT 4 | 0.03288 | 0.17832 | 0.00000 | 1.00000 | 36.50 |
| 5 | WAIT 5 | 0.00000 | 0.00000 | 0.00000 | 0.00000 | 36.50 |
| 6 | WAIT 6 | 0.00000 | 0.00000 | 0.00000 | 0.00000 | 36.50 |
| 7 | WAIT 7 | 0.01370 | 0.11624 | 0.00000 | 1.00000 | 36.50 |
| 8 | WAIT 8 | 0.37808 | 0.74360 | 0.00000 | 2.00000 | 36.50 |
| 9 | WAIT 9 | 2.48767 | 1.20410 | 0.00000 | 4.00000 | 36.50 |
| 10 | WAIT 10 | 0.00000 | 0.00000 | 0.00000 | 0.00000 | 36.50 |
| 11 | UTIL. 1 | 0.26027 | 0.43878 | 0.00000 | 1.00000 | 36.50 |
| 12 | UTIL. 2 | 0.66575 | 0.47173 | 0.00000 | 1.00000 | 36.50 |
| 13 | UTIL. 3 | 0.00000 | 0.00000 | 0.00000 | 0.00000 | 36.50 |
| 14 | UTIL. 4 | 0.18904 | 0.39154 | 0.00000 | 1.00000 | 36.50 |
| 15 | UTIL. 5 | 0.13699 | 0.34383 | 0.00000 | 1.00000 | 36.50 |
| 16 | UTIL. 6 | 0.14794 | 0.35504 | 0.00000 | 1.00000 | 36.50 |
| 17 | UTIL. 7 | 0.20000 | 0.40000 | 0.00000 | 1.00000 | 36.50 |
| 18 | UTIL. 8 | 0.31781 | 0.46562 | 0.00000 | 1.00000 | 36.50 |
| 19 | UTIL. 9 | 0.89863 | 0.30182 | 0.00000 | 1.00000 | 36.50 |
| 20 | UTIL. 10 | 0.00000 | 0.00000 | 0.00000 | 0.00000 | 36.50 |

Figure 6. (Continued)

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